Bioinformatics

CS300

Crash course:

Structure and Replication of DNA

Week 2, deck 3

Fall 2022

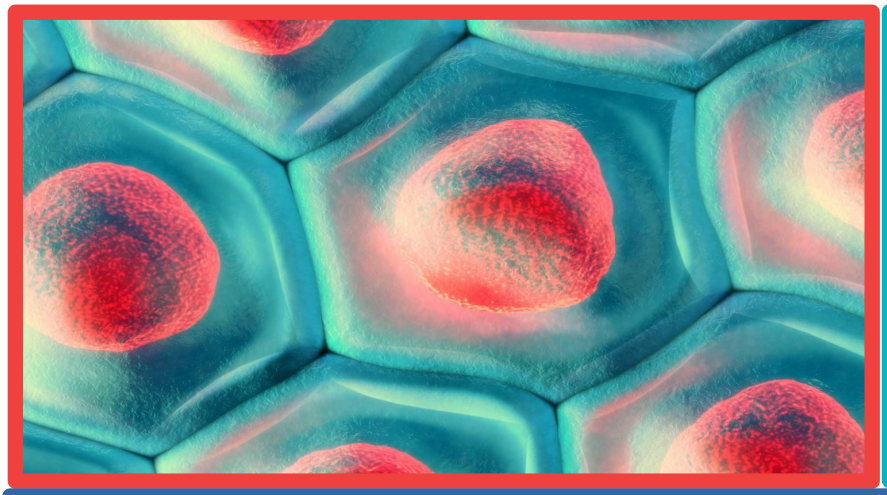
Oliver BONHAM-CARTER

Some Background in Biology

What's a MAJOR Commonality Here?

Organisms Have Genetic Systems!

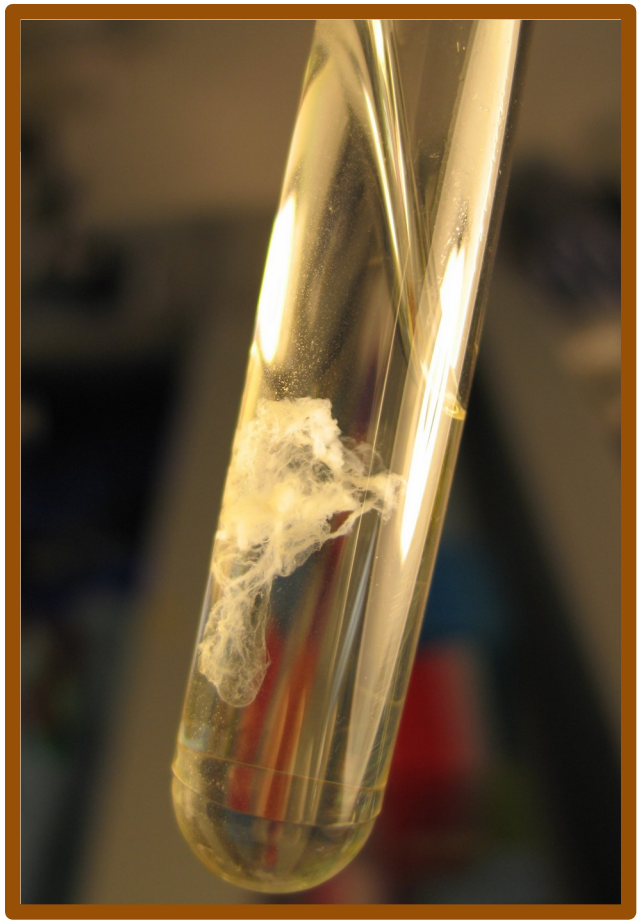
… *And DNA is Often the Genetic Language*



What Does Natural DNA look Like?

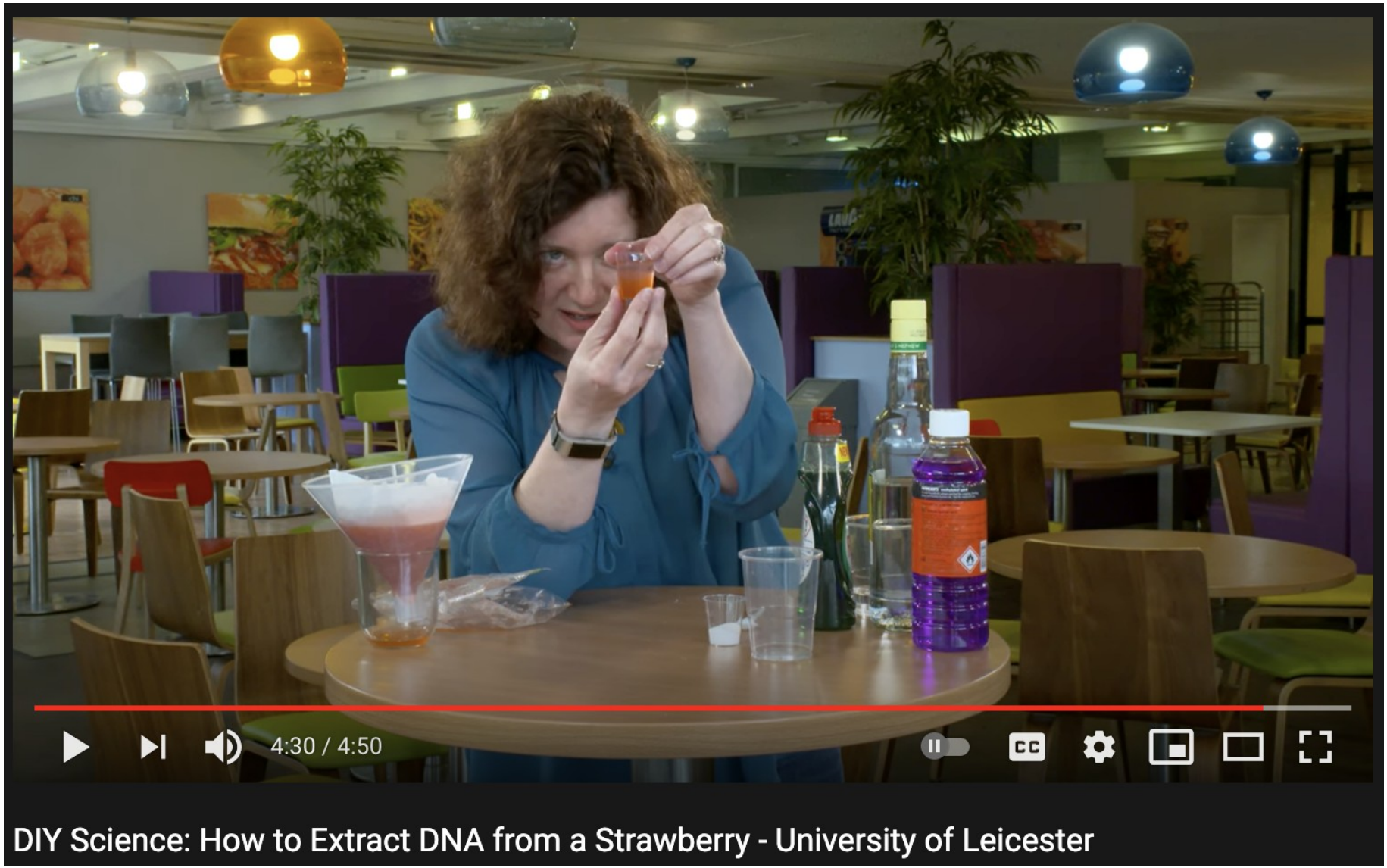
NOT like this!

Like this!



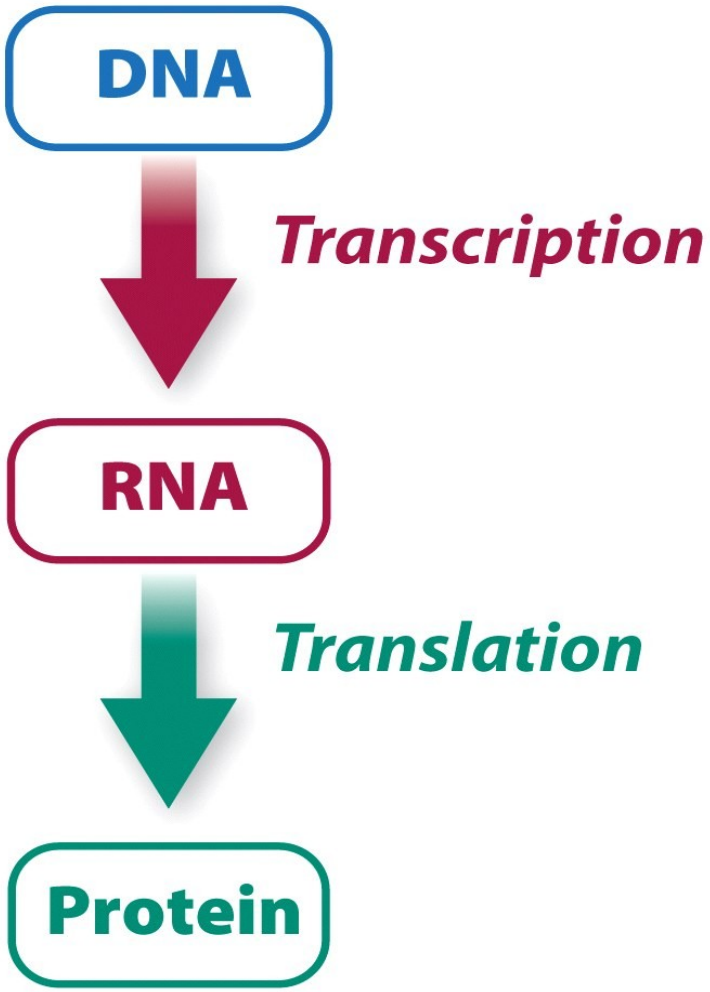
Like this!

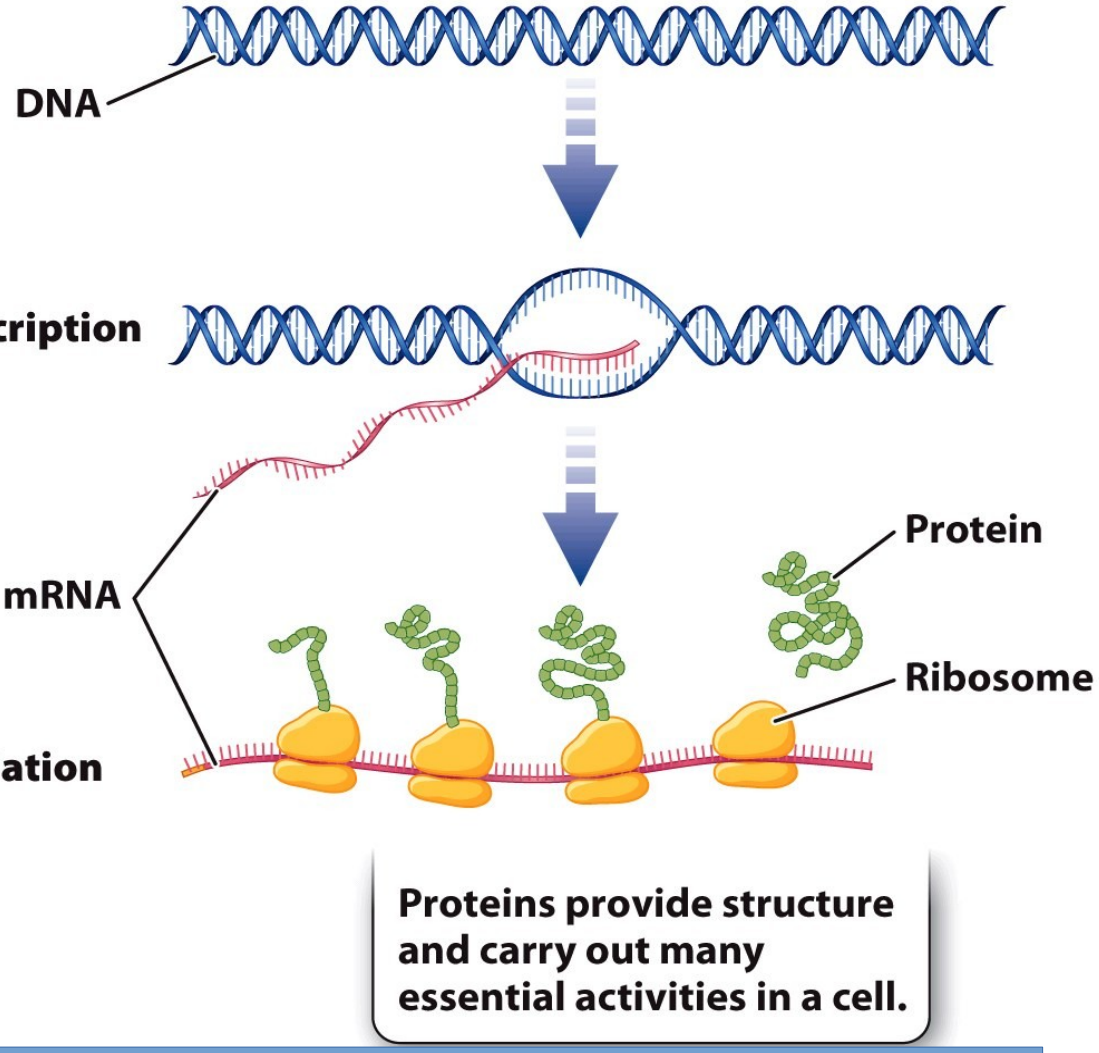
DIY: Strawberry DNA Extraction



Link: https://www.youtube.com/watch?v=JofXXyFZn38

Central Dogma of Molecular Biology

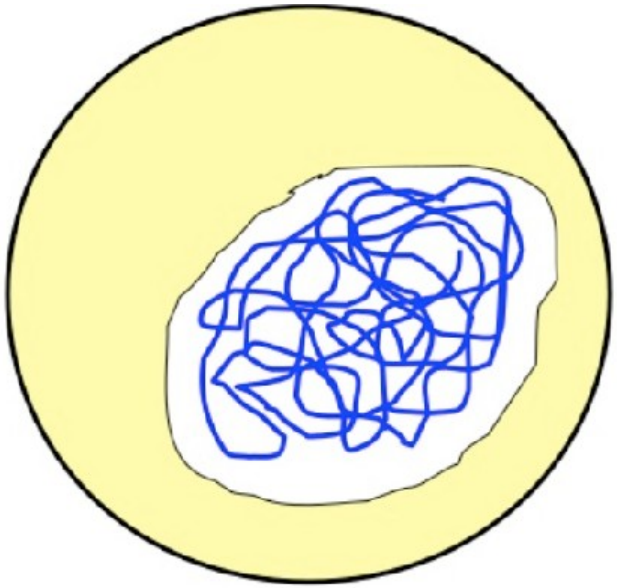


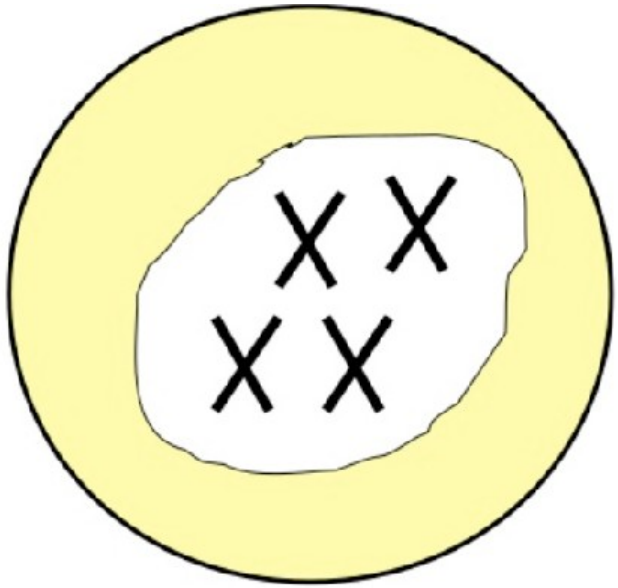


Dogma: *a principle, or set of principles, laid down by an authority as incontrovertibly true.*

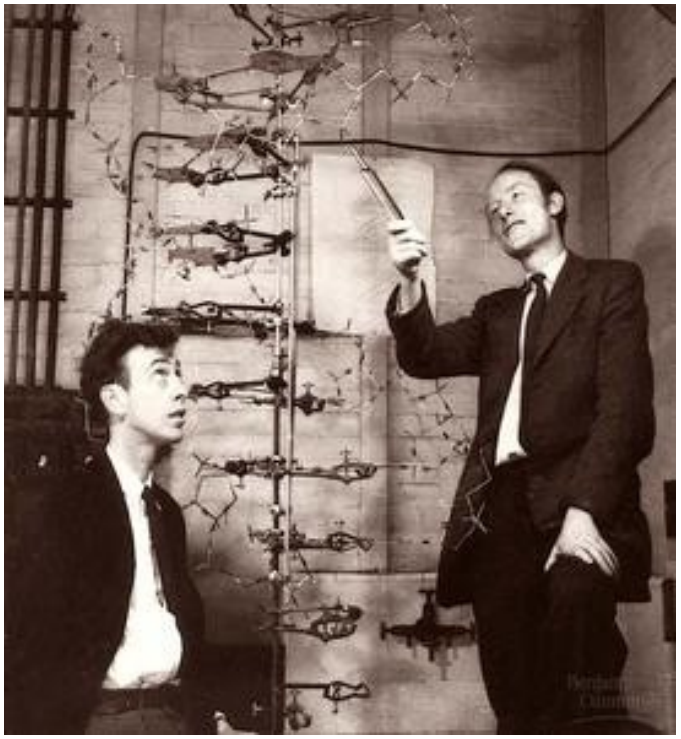
What is DNA?

- Found in the nucleus of a cell in two different structures: chromatin and chromosomes
- Genetic Material (Life's *blueprints*)
- *Written* inherited characteristics (genes)

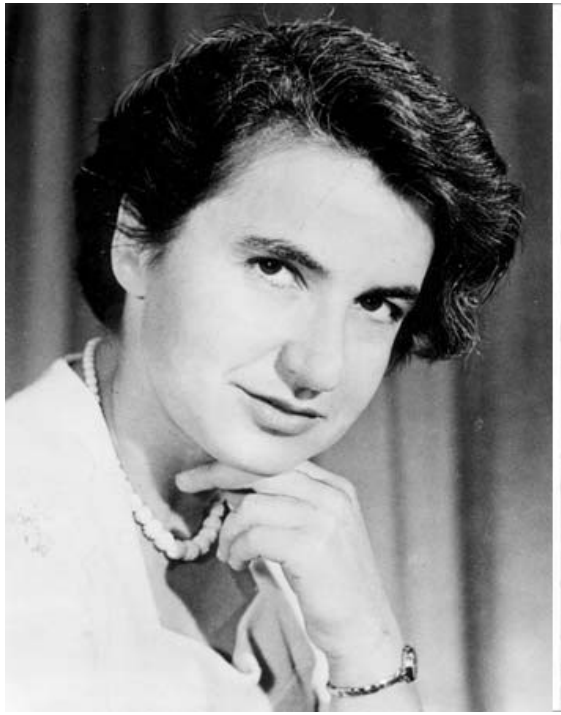


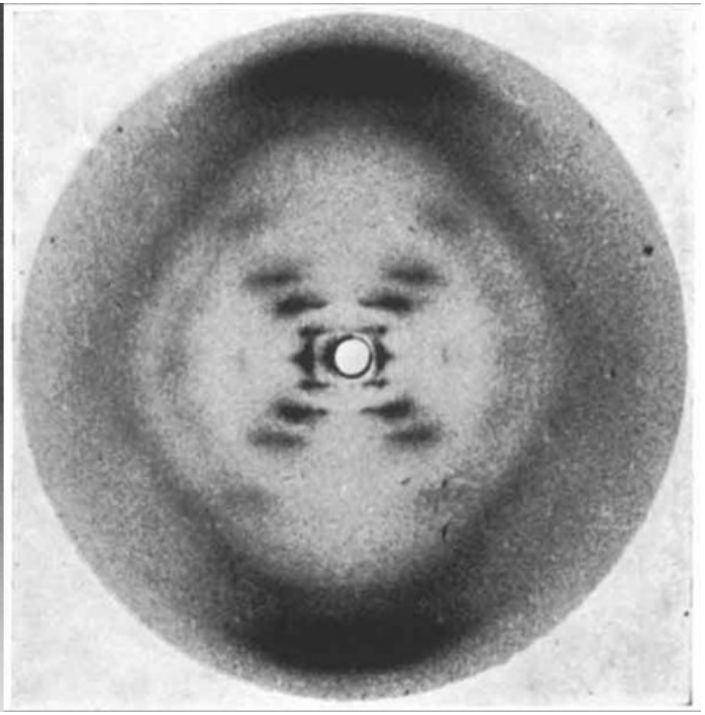


DNA Double Helix:
Discovery of Structure

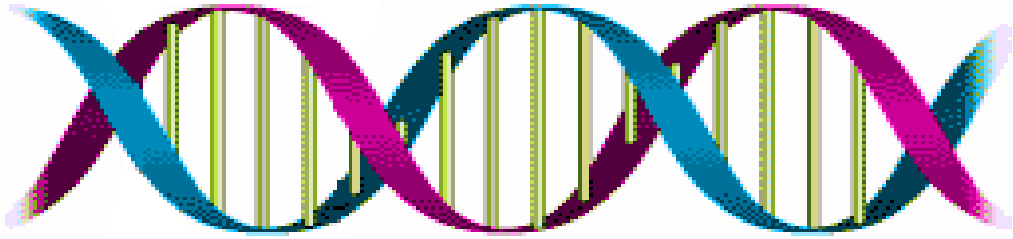


Watson and Crick, 1953

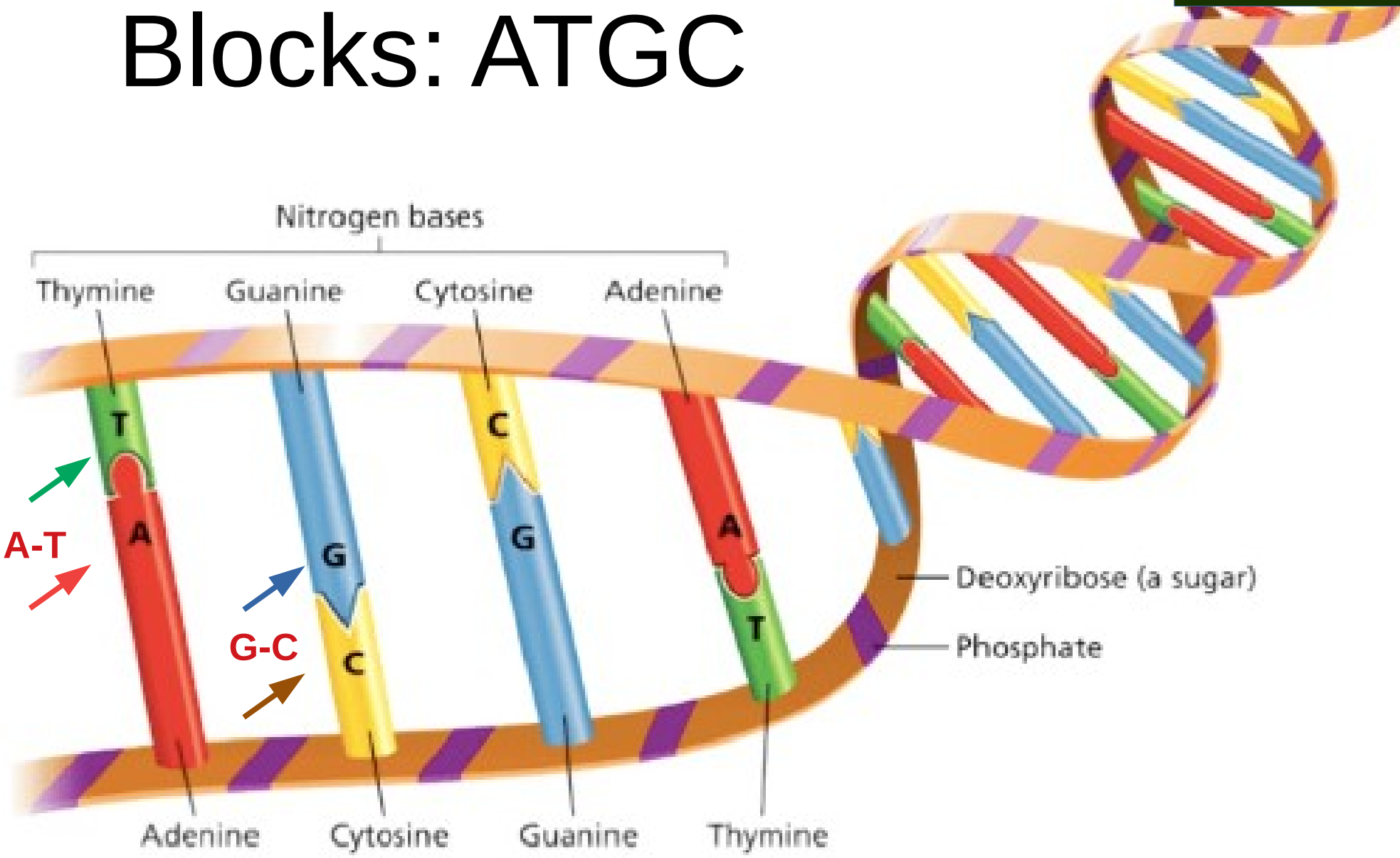




Rosalind Franklin and her data from x-ray crystallography

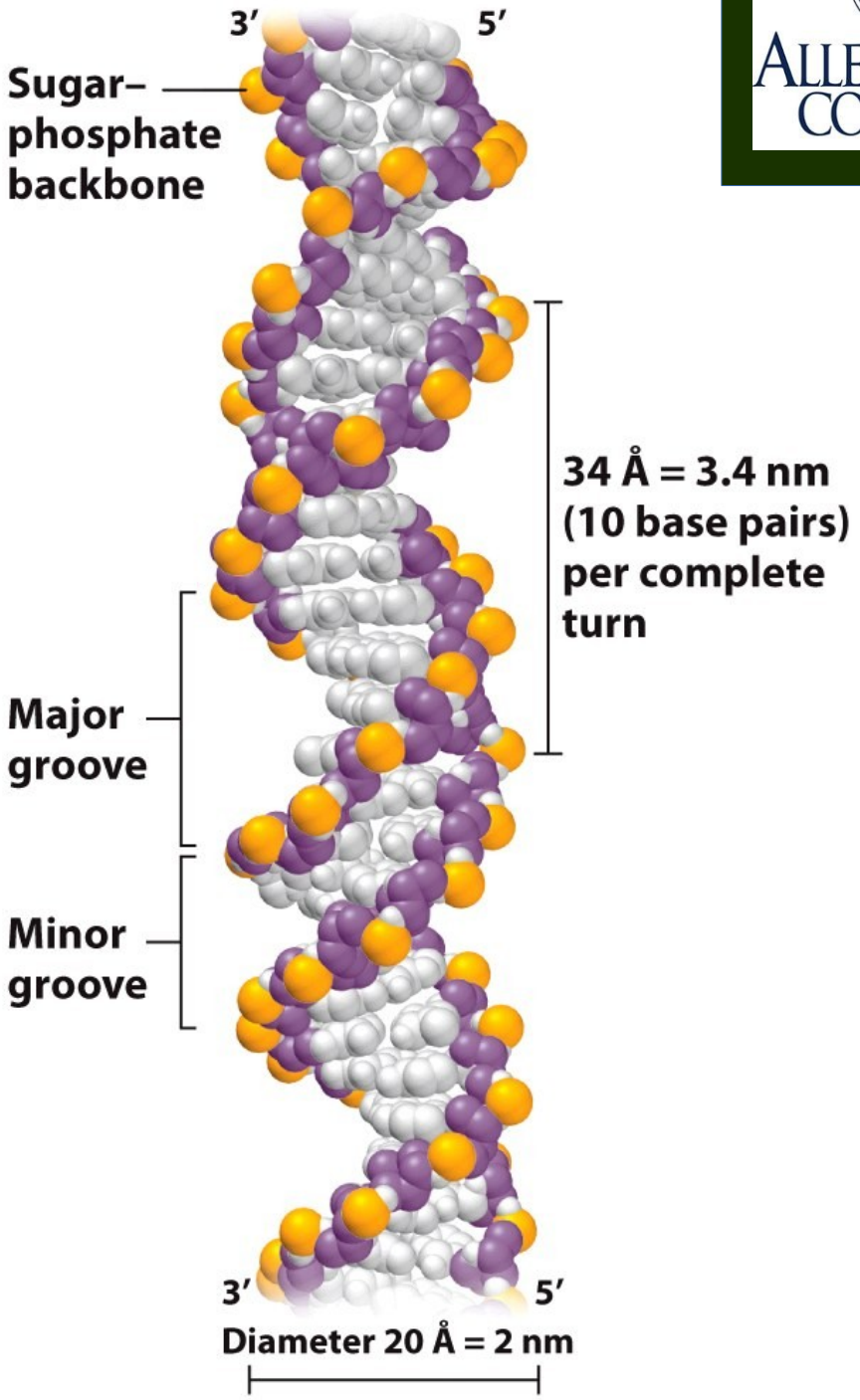


Molecular Building Blocks: ATGC



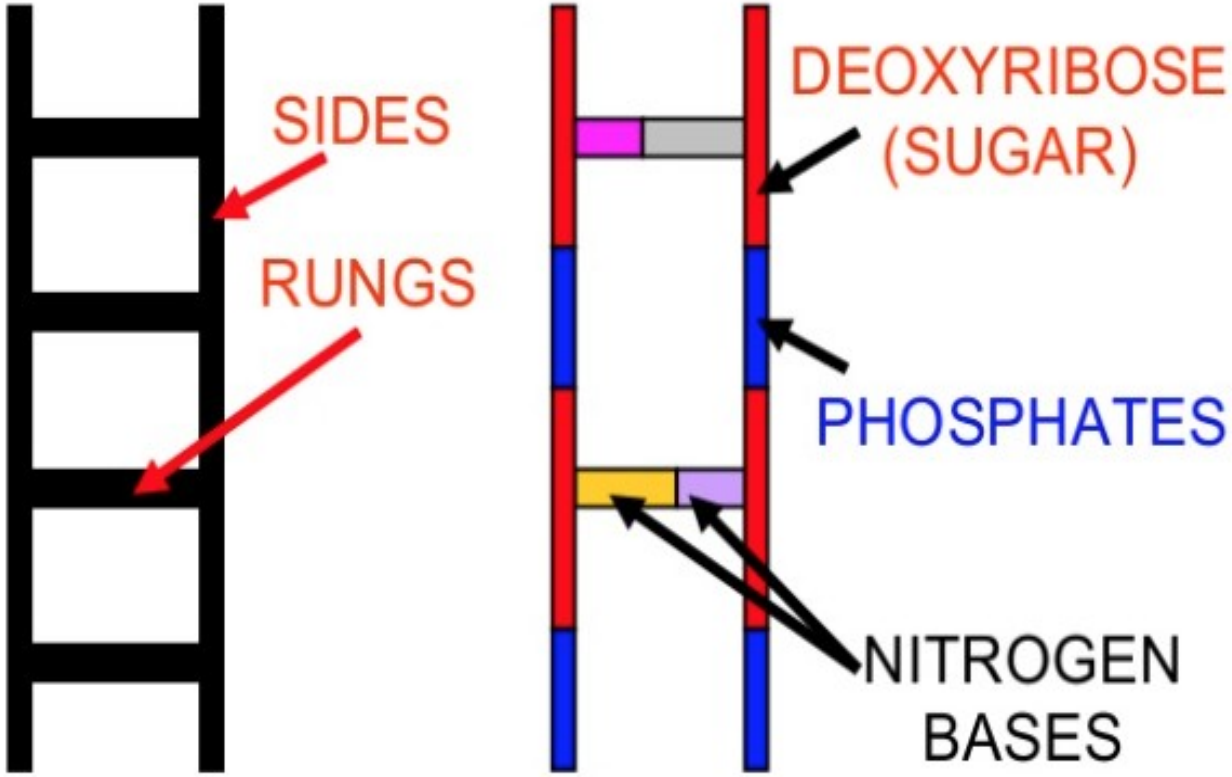
DNA Molecule

- Double-stranded
- Diameter – 2nm
- Helix
  - Complete turn = 10bp, 3.4nm
  - Major groove
  - Minor groove



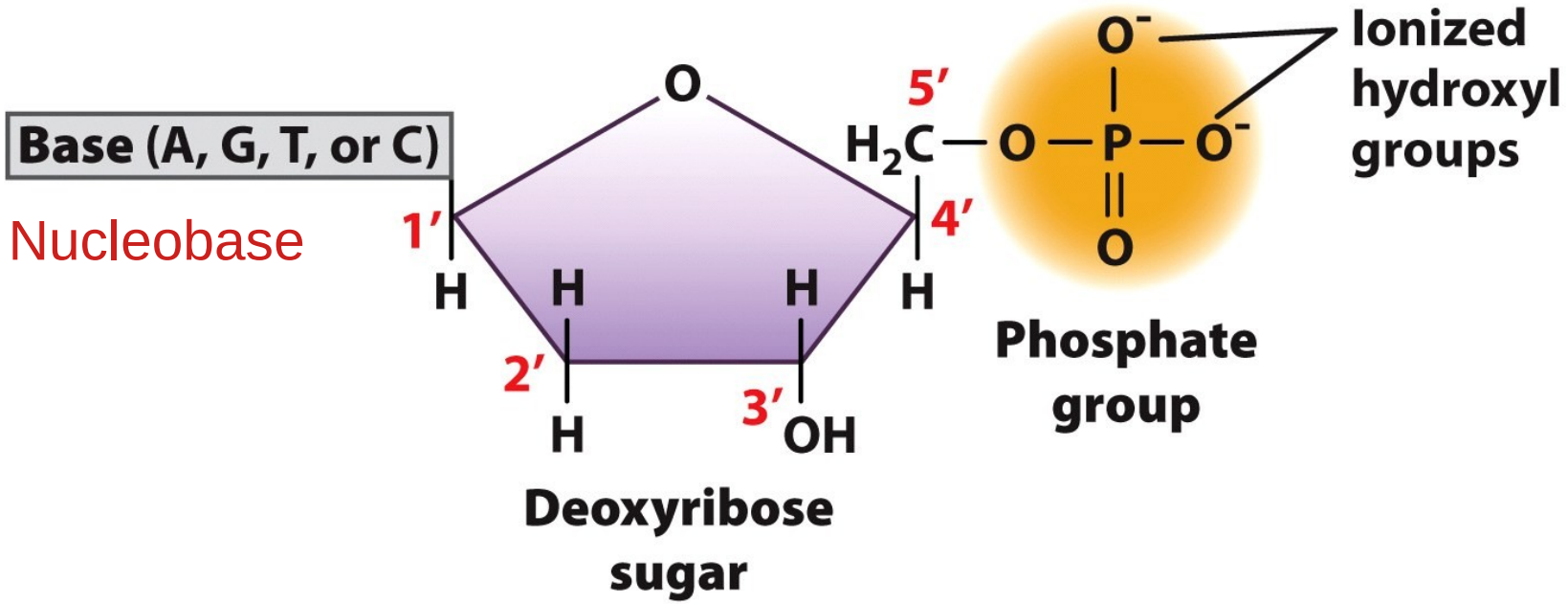
DNA Structure

- Formed like a twisted ladder
- There are two sides of the ladder
- Sugar (deoxyribose)
- Phosphates
- Alternating
- Rungs of the ladder
- Nitrogenous bases



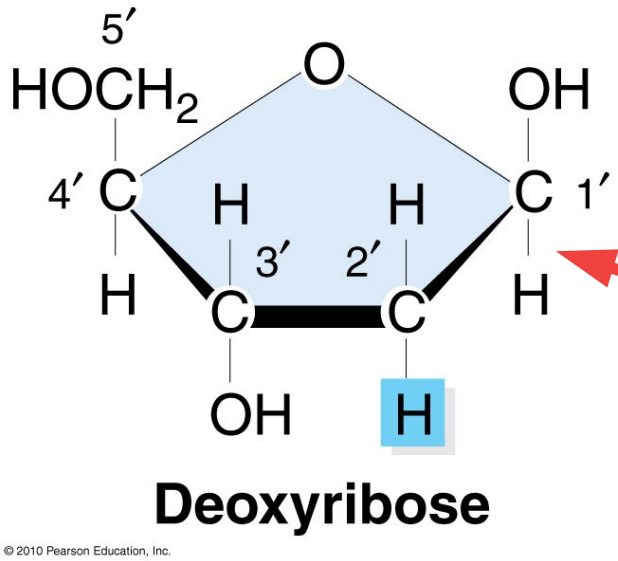
Nucleotides

- The supporting of rungs in the “ladder” (base pairs).
- *Nucleotides: composed of three subunit molecules:*
  - *a nucleobase,*
  - *a five-carbon sugar (ribose or deoxyribose),*
  - *a phosphate group consisting of one to three phosphates.*
  - *The four nucleobases in DNA: guanine, adenine, cytosine and thymine; Note: in RNA, uracil is used in place of thymine.*



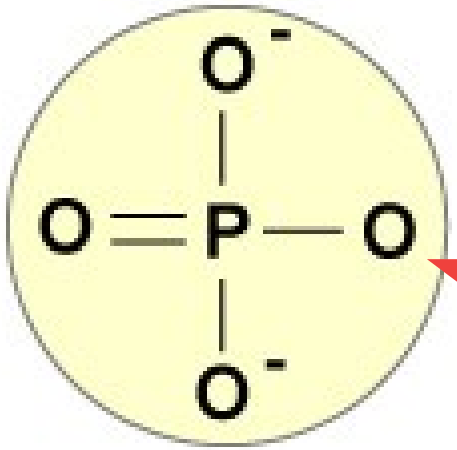
DNA Structure

Deoxyribose **S**ugar



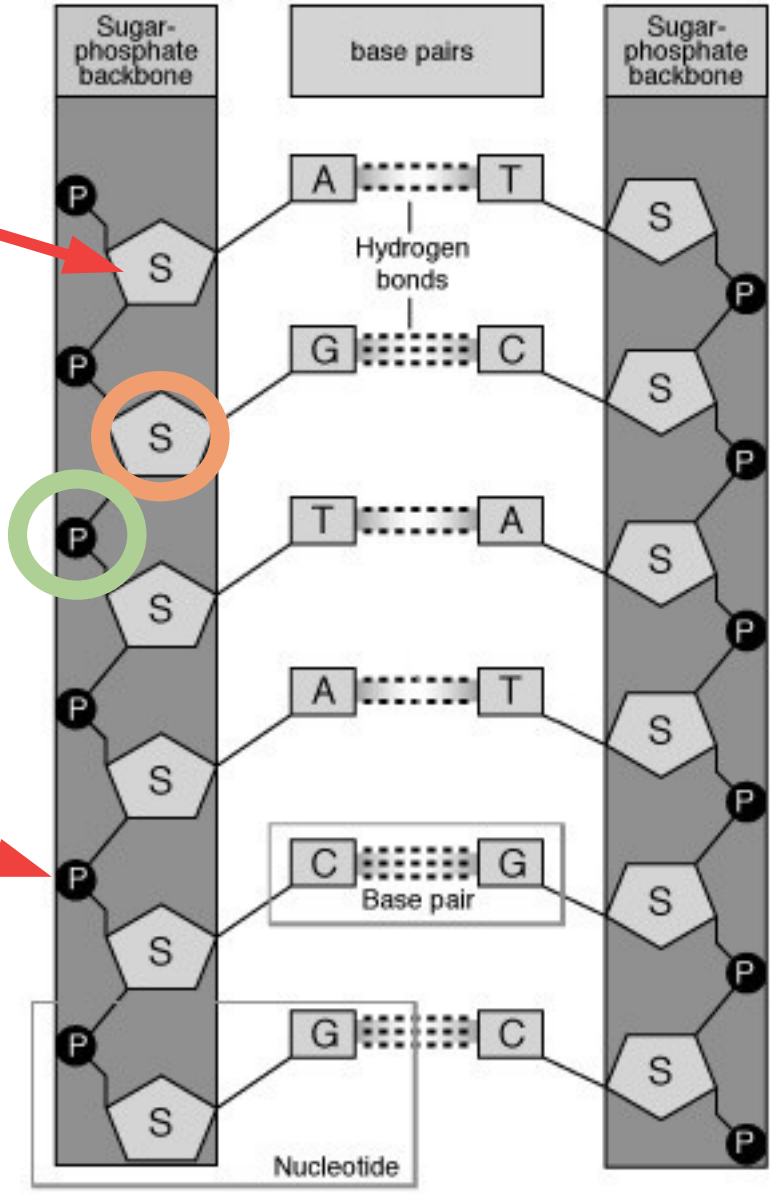
Deoxyribose

Phosphate



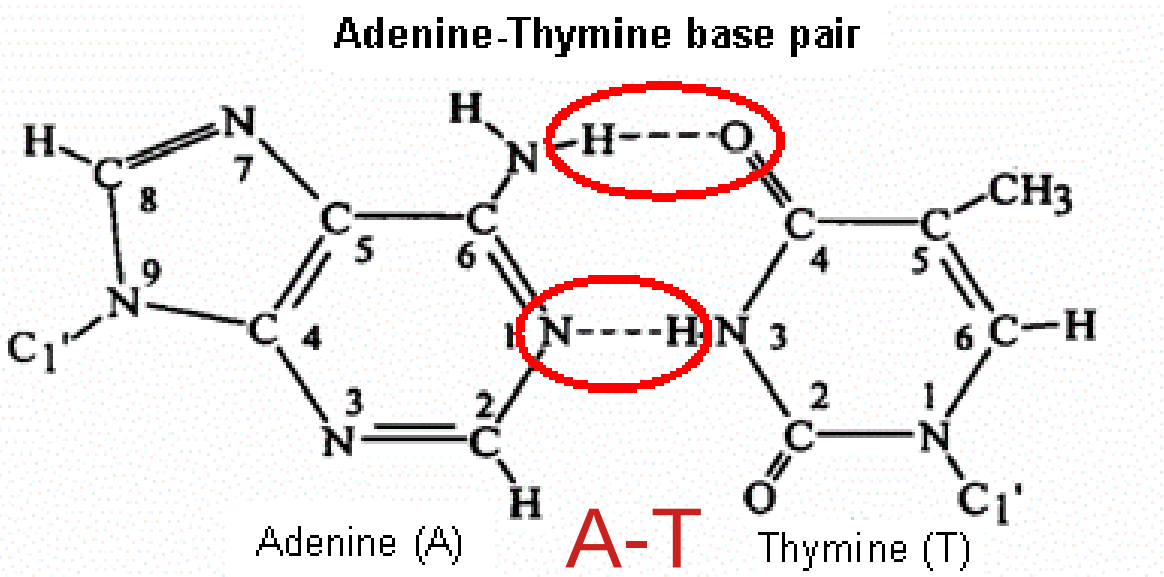
Phosphate group

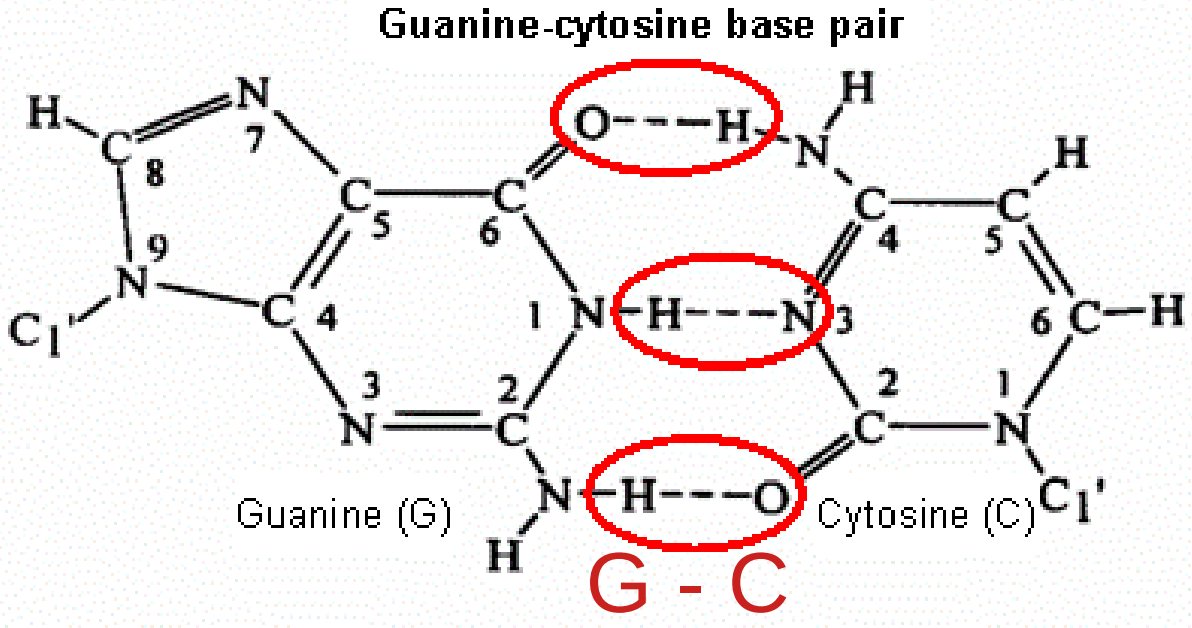
Phosphorus surrounded by oxygens



Base to Base Bonds: How do nitrogenous bases pair?

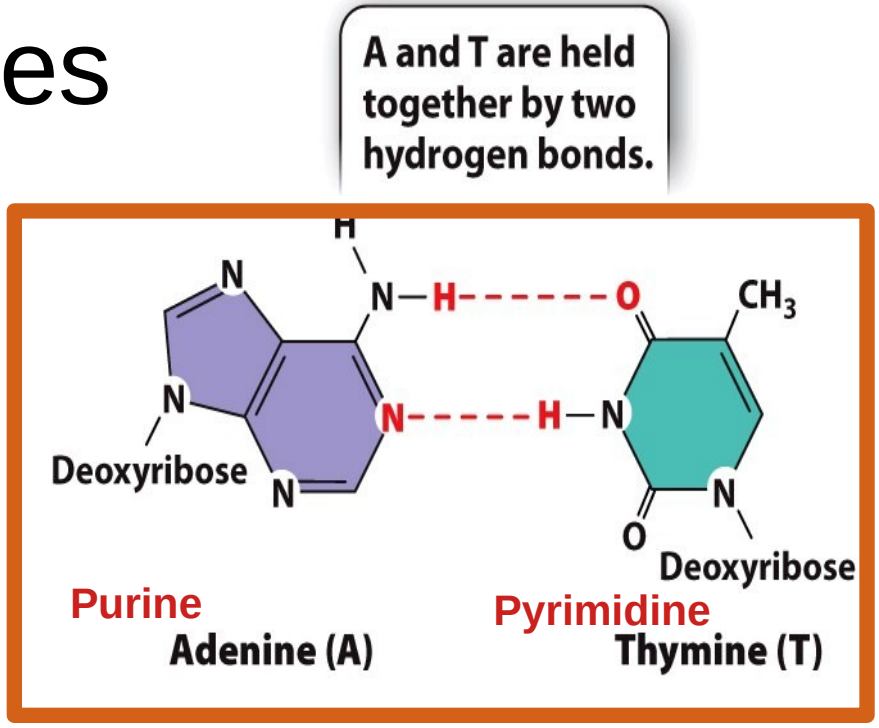
- Base-Specific bonding
- Preserves distance between (DNA's) backbones
- Hydrogen bonds
- Key to replication
- A-T's have **two** bonds
- G-C's have **three** bonds

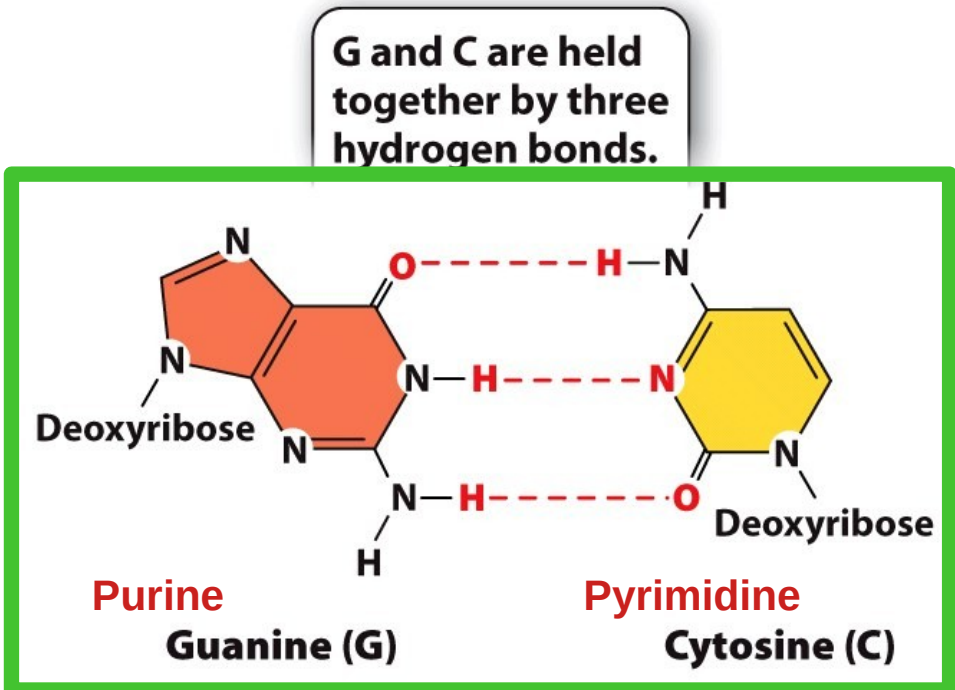




Purines and Pyrimidines

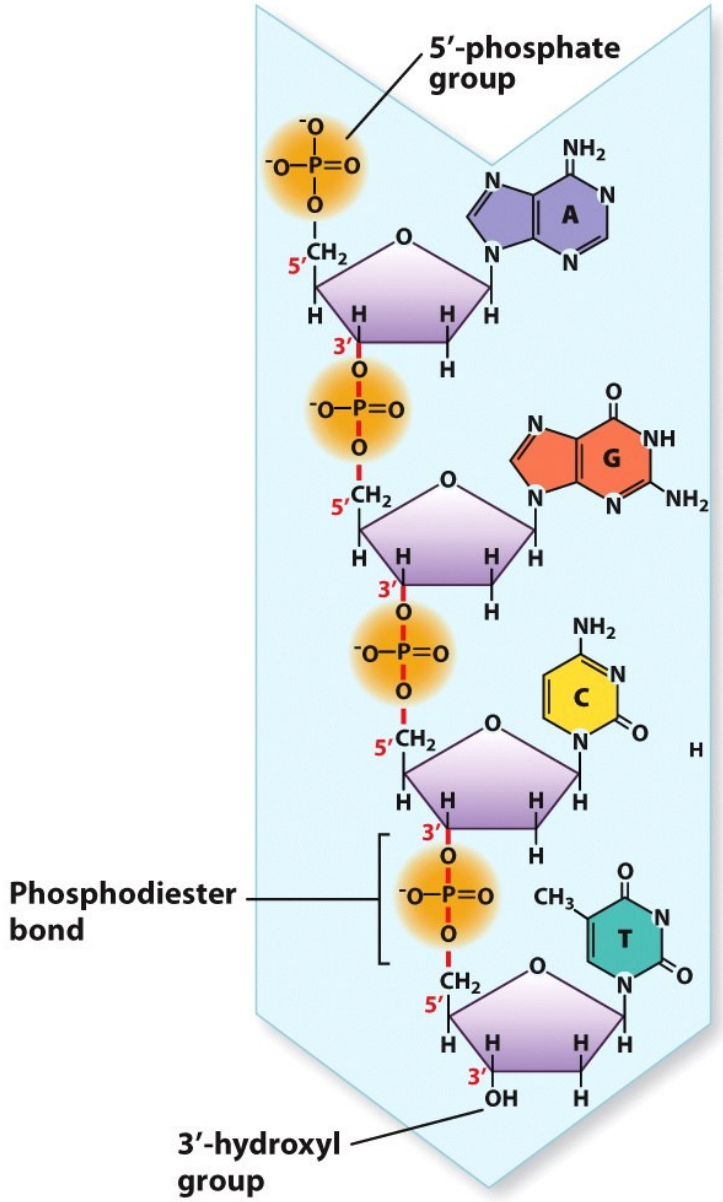
- Purines and Pyrimidines are nitrogenous bases that comprising the two different types of nucleotide bases in DNA and RNA.
- The two-carbon nitrogen ring bases (adenine and guanine) are purines, while the one-carbon nitrogen ring bases (thymine and cytosine) are pyrimidines.
- **Purines**: adenine and guanine
- **Pyrimidine**: thymine, cytosine, and uracil
- Purines include a number of biologically important compounds, such as adenosine, caffeine, uric acid, and the two bases adenine and guanine, which are components of DNA and RNA.





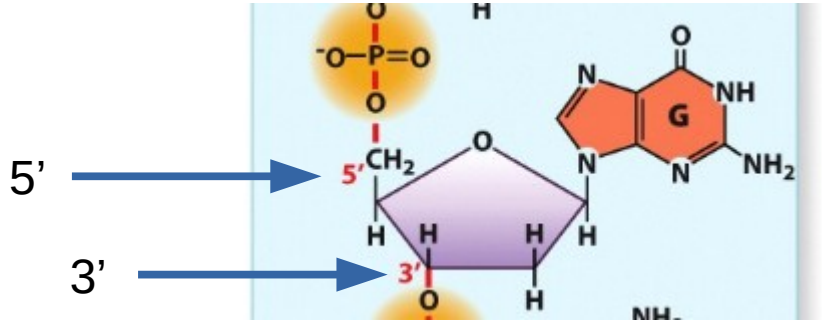
DNA Read in 5’ to 3’ Direction

- Nucleotides are joined by phosphodiester bonds
  - phosphate to sugar
  - covalent bonds
- Polarity
  - 5’ end – phosphate group
  - 3’ end – hydroxyl group
- AntiParallel: DNA read in 5’ to 3’ direction

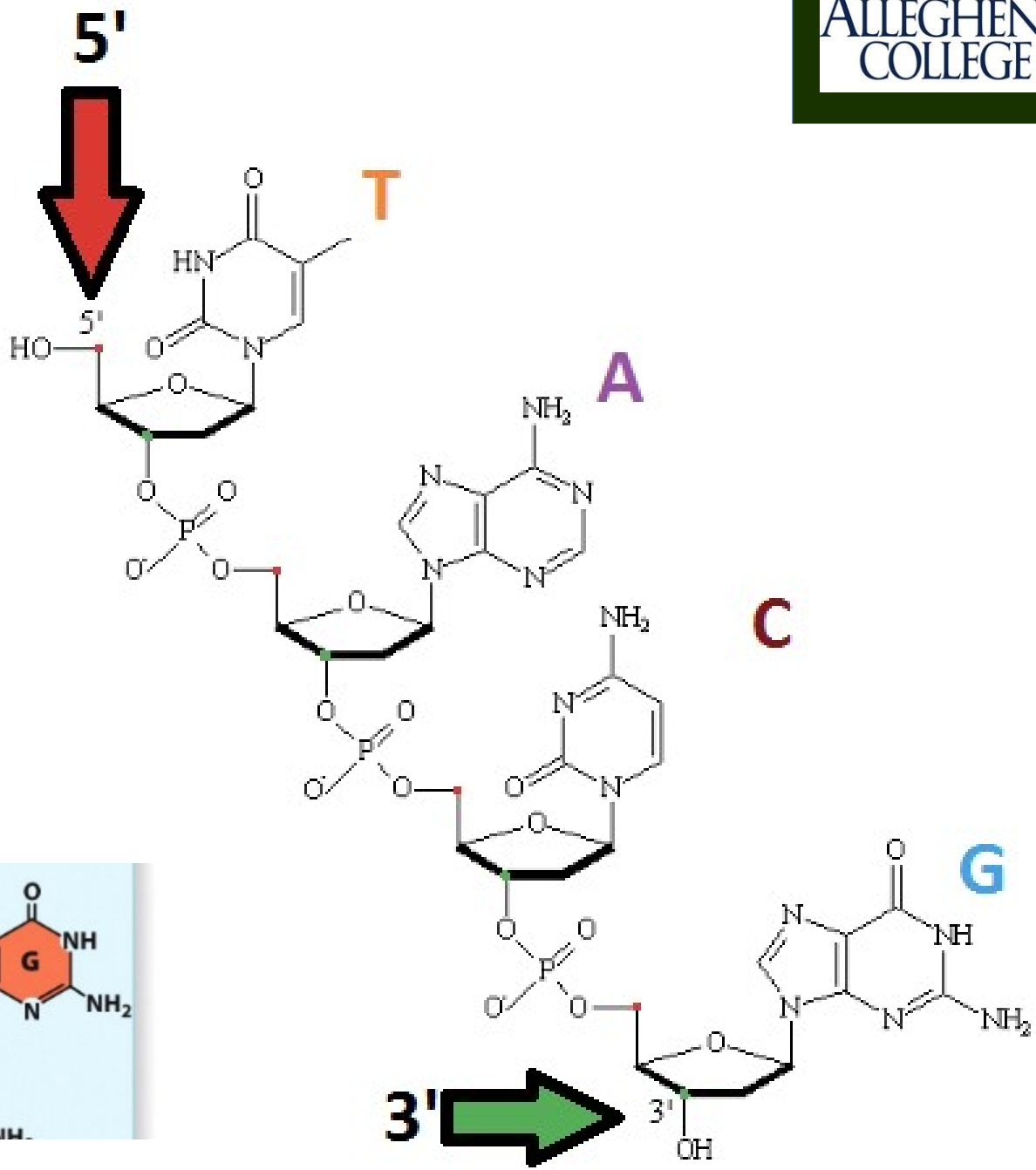


5’ and 3’ Ends?

- A key feature of all nucleic acids is that they have two distinctive ends: **The 5' (5-prime) and 3' (3-prime) ends.**
- This terminology refers to the 5’ and 3’ carbons on the sugar.
- For both DNA and RNA, the 5' end bears a phosphate, and the 3' end a hydroxyl group.

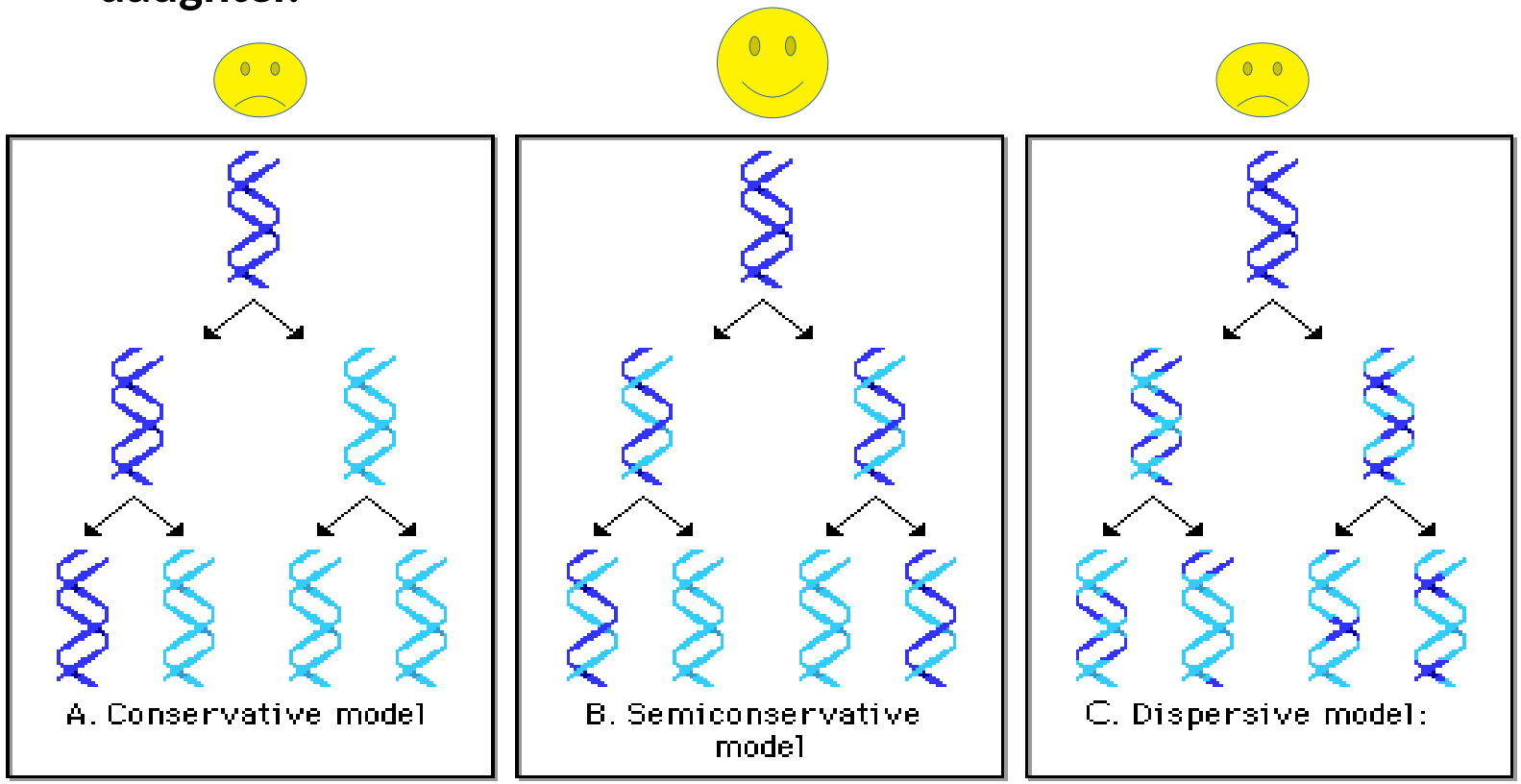


Note the ordering of carbons, hence 5’ to 3’

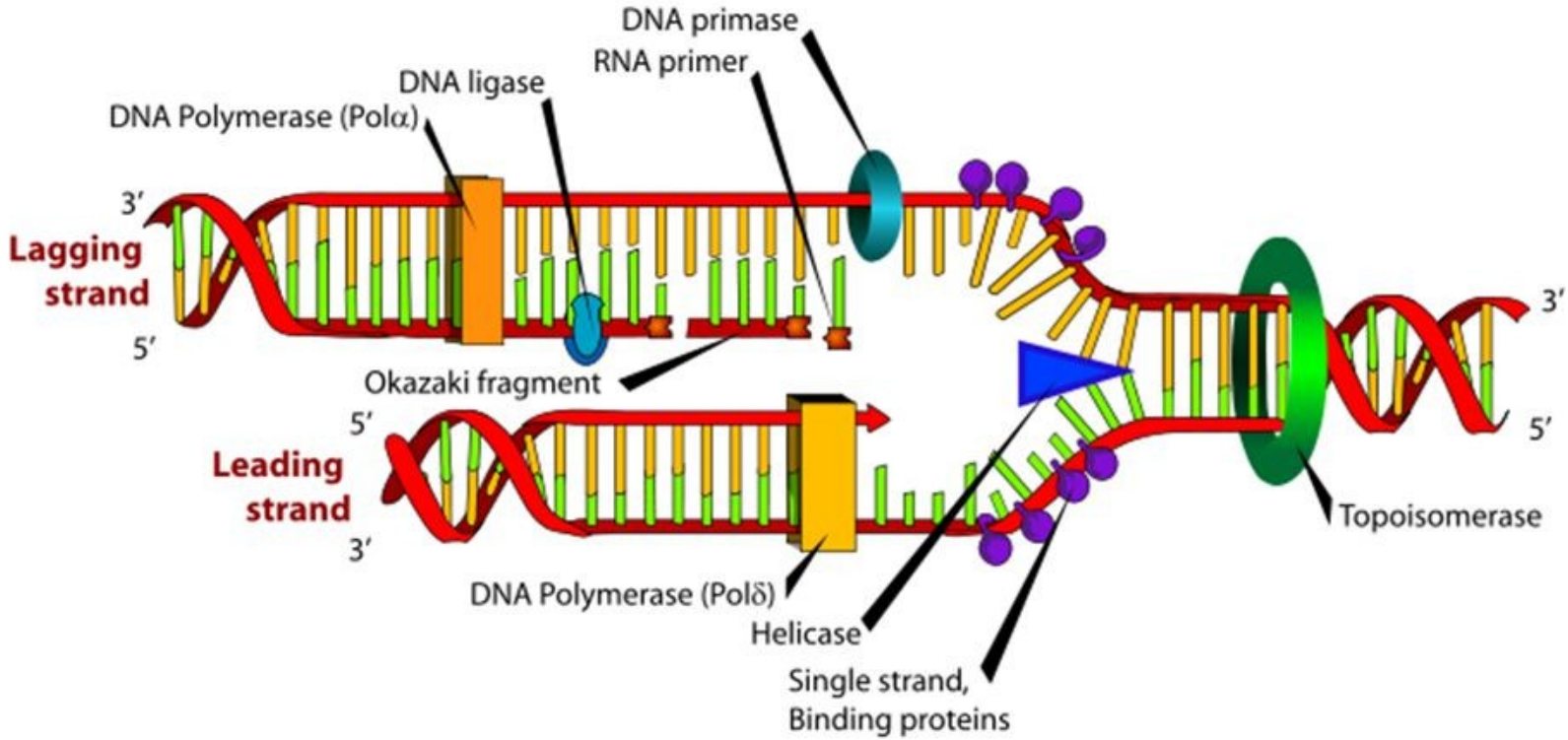


Proposed Mechanisms of Replication Process

1. The two sides of the parent molecule unwind/unzip
2. Daughter strands are synthesized using parent strands as templates
3. Parent/daughter duplex winds back together
   - **Semi-conservative: a 2nd gen helix composed of parental strand and one daughter.**

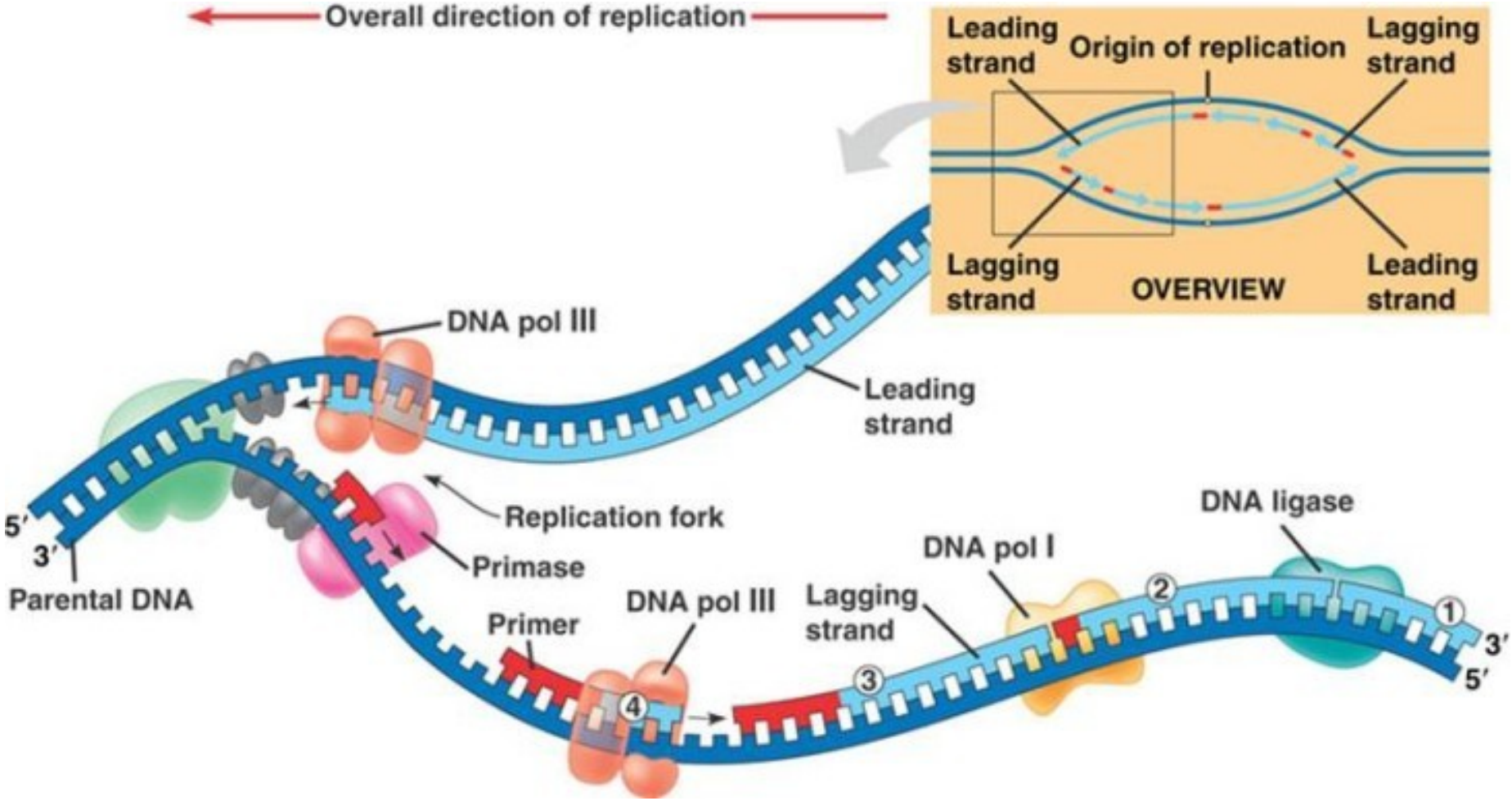


DNA Replication Process



http://www.hhmi.org/biointeractive/dna-replication-schematic

DNA Replication Enzymology



http://www.hhmi.org/biointeractive/dna-replication-basic-detail

http://highered.mheducation.com/sites/0073525324/student_view0/chapter20/dna_replication_fork.html

1. Test Your Understanding

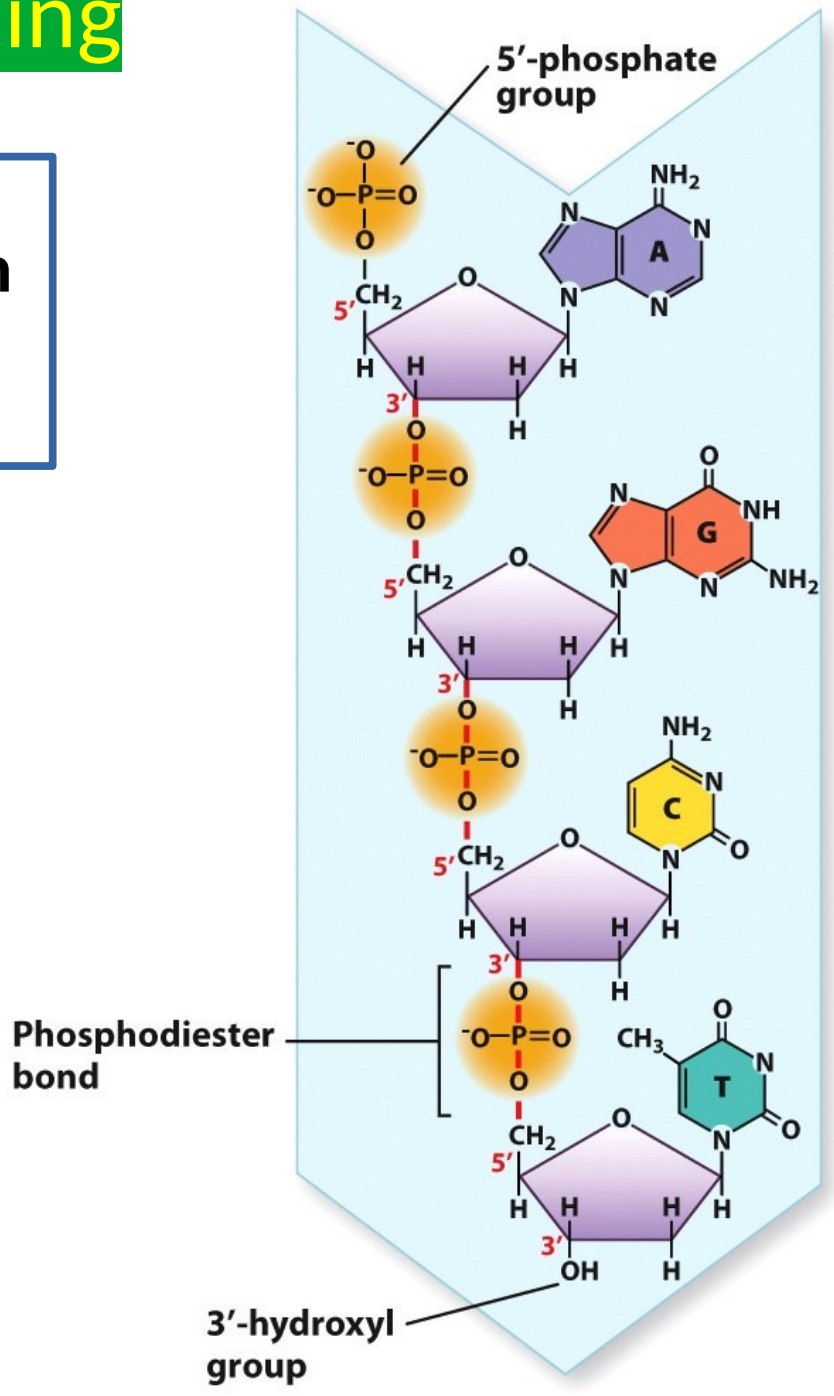
In the DNA sequence 5'–AGCT–3', the phosphodiester linkage between the adenine and the guanine connects:

A. The 2' end of the adenine to the 4' end of the guanine.

B. The 5' end of the adenine to the 3' end of the guanine.

C. The 5' end of the guanine to the 1' end of the adenine.

D. The 3' end of the adenine to the 5' end of the guanine.



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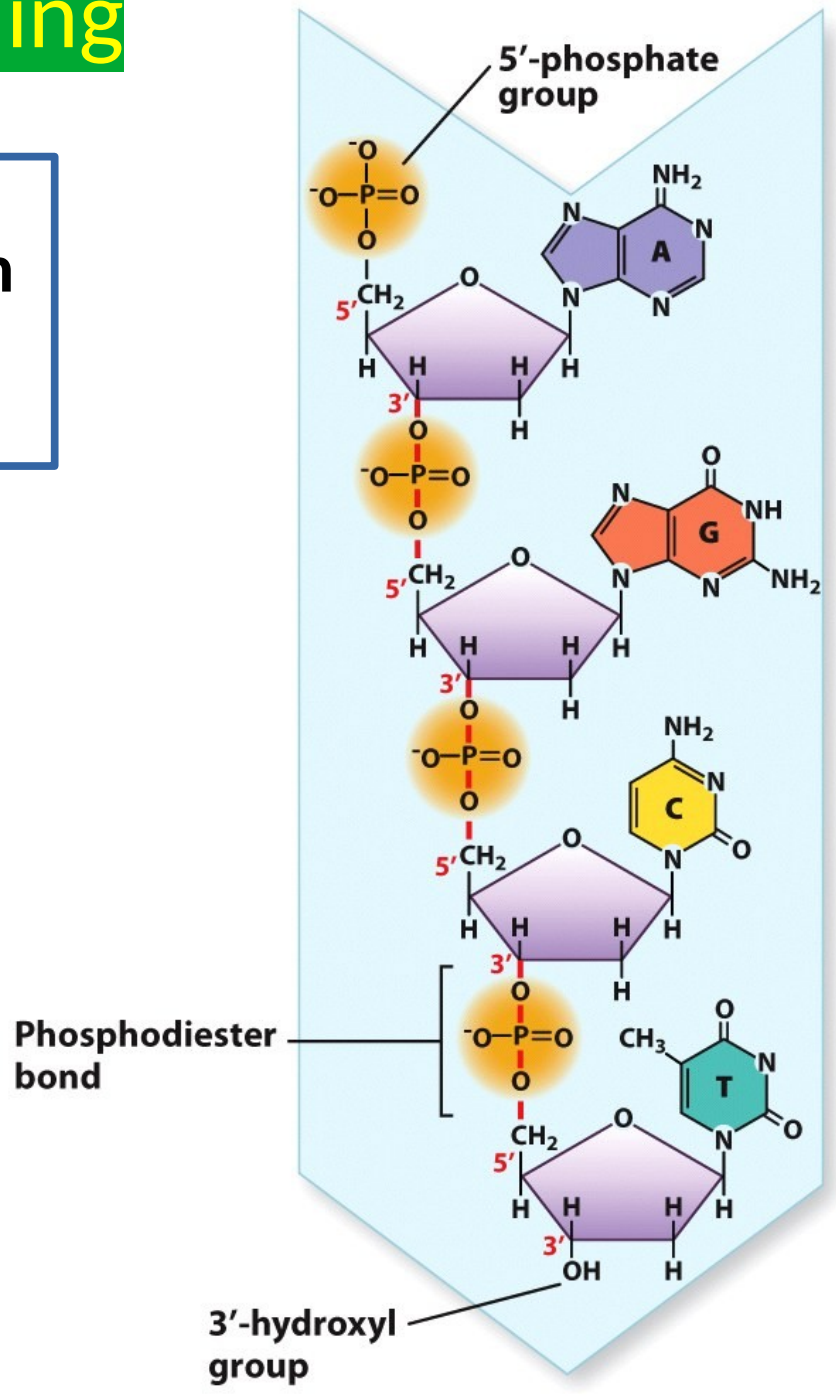
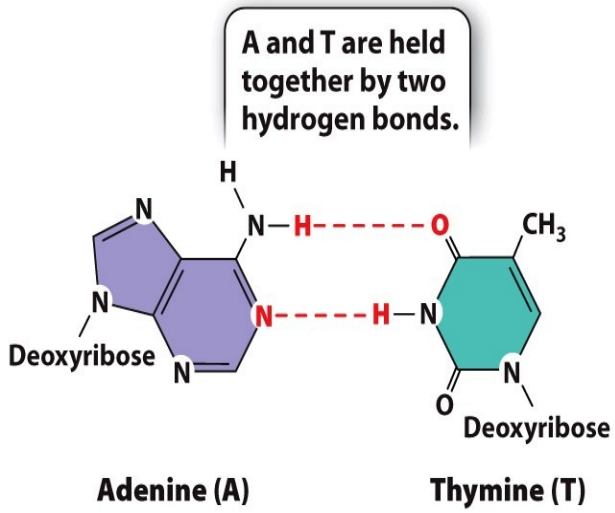


2. Test Your Understanding

In the DNA of certain bacterial cells, 16% of the nucleotides are adenine. What are the percentages of the other nucleotides in the bacterial helix of DNA?

A. 34% thymidine, 34% guanine, 16% cytosine
B. 34% uracil, 16% guanine, 16% cytosine
C. 16% thymidine, 34% guanine, 34% cytosine
D. 34% thymidine, 16% guanine, 34% cytosine



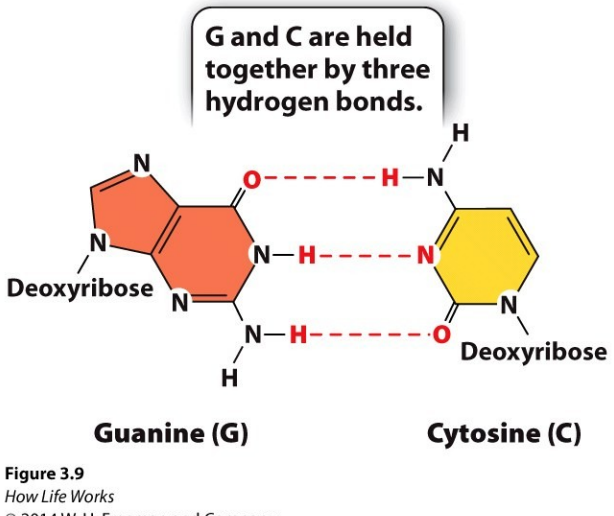
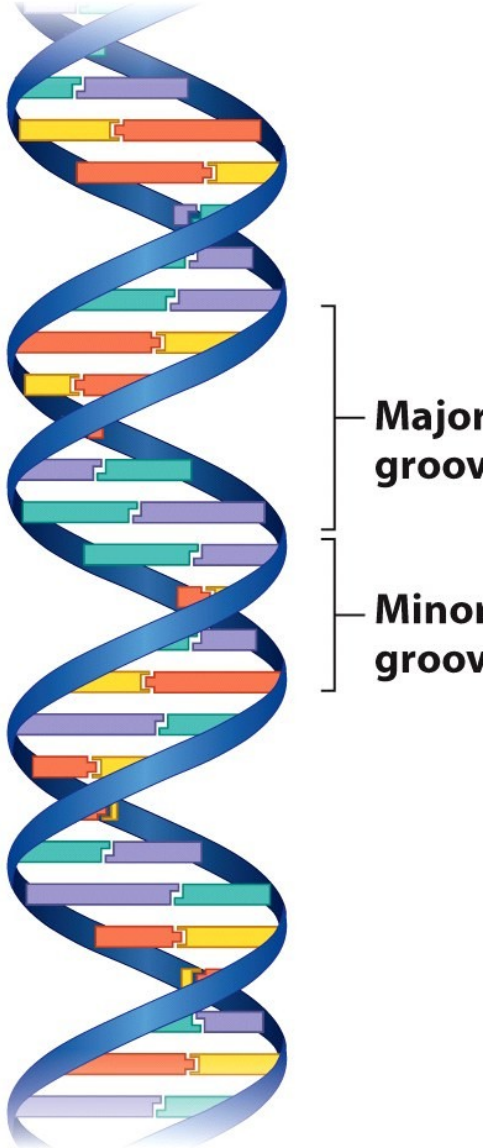


Figure 3.9
How Life Works



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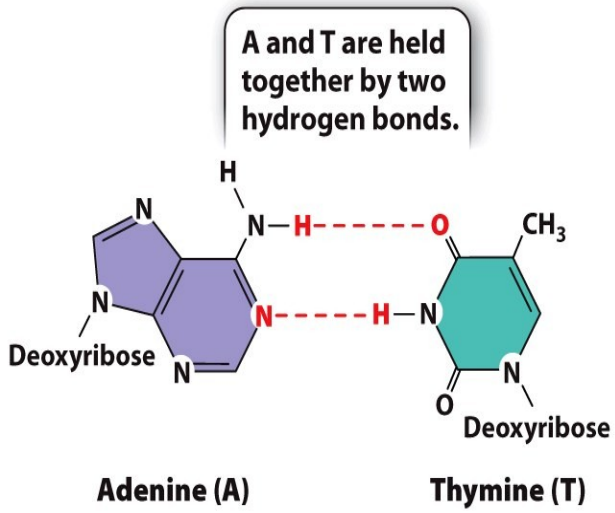


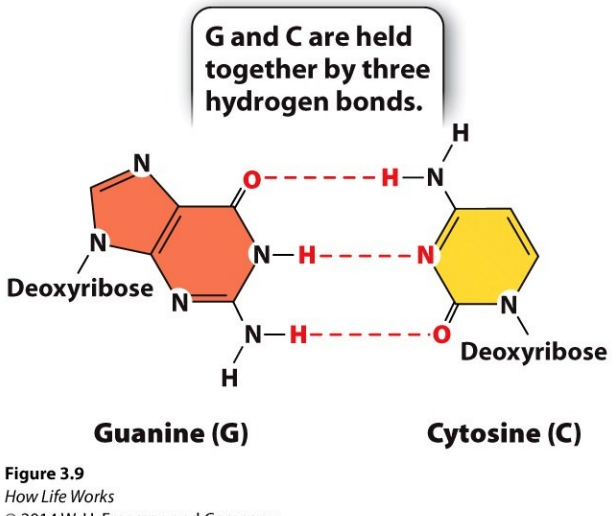
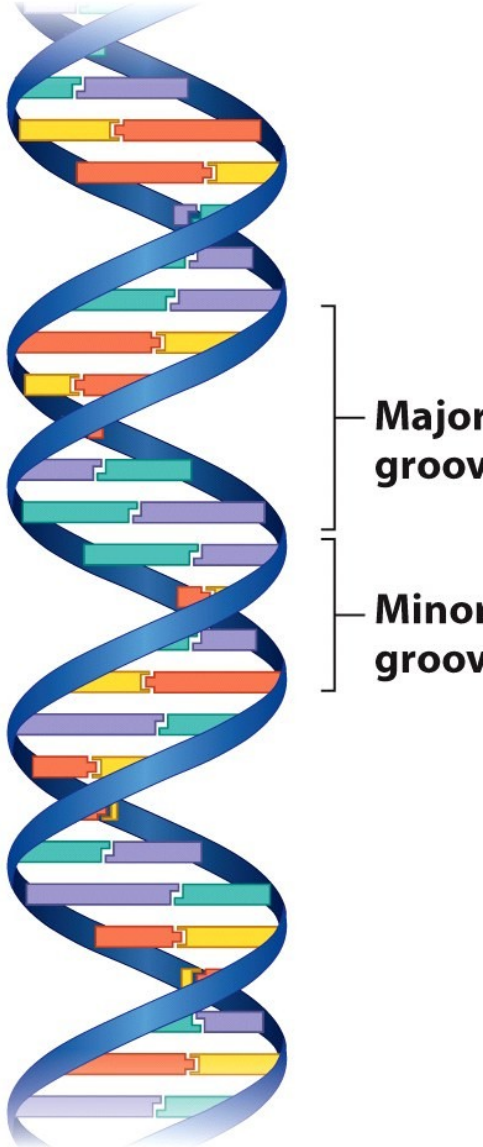


Figure 3.9
How Life Works



3. Test Your Understanding

DNA replicates in a semi-conservative manner. This means:

a) one daughter strand is synthesized as a large fragment while the other is synthesized in smaller fragments, both in the 5'-3' direction
b) every newly formed double-stranded DNA molecule consists of one parental strand and one daughter strand
c) every newly formed double-stranded DNA molecule is comprised of two new daughter strands
d) one daughter strand is synthesized as a large fragment in the 5'-3' direction while the other is synthesized in smaller fragments in the 3'-5' direction

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Supporting Videos

- The Double Helix (Documentary about DNA discovery, 17 mins)
  - http://media.hhmi.org/biointeractive/films/Double_Helix.html
- The Chemical Structure of DNA (3 mins)
  - http://www.hhmi.org/biointeractive/chemical-structure-dna
- The Structure of DNA (6 mins)
  - https://www.youtube.com/watch?v=o_-6JXLYS-k
- The def of 5' and 3' strands (1.5 mins)
  - https://www.youtube.com/watch?v=qWZYpHSXvJo